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AND ABSTRACT OF THE LITERATURE

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The Ventilation and Heating of Factories

Summary of the National Safety Council Study of Benzol Poisoning

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CHRONIC POISONING BY TIN AND ITS SALTS*

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POISONING by tin or its salts is a very rare occurrence in industry. In fact a search of the literature fails to reveal the report of a single case. The occurrence of a possible case, therefore, justifies a report, but since the symptomatology is unknown, a positive diagnosis cannot be made.

CASE REPORT

The case now to be reported is that of a German man, aged 66. For twenty years the patient's occupation has brought him more or less in close contact with tin, for the most part with tin tetrachloride in connection with the manufacture of silk. For the past ten years it has been his business to mix up a solution of tin tetrachloride in hydrochloric acid in the following manner: The liquid tetrachloride is kept in a large drum, from which it is conveyed to the tank containing the hydrochloric acid by means of a hose. The arrangement is a crude one and a great amount of fume is liberated during the process. To the uninitiated, the fumes are unbearably irritating to the nose, eyes, and trachea; but the patient, who has been exposed every day and sometimes twice a day for years, appears to mind the fumes very little and laughs at the coughing and sneezing of the spectators. It is evident that, although the exposure is brief (probably not more than ten or fifteen minutes each time), the man inspires a large amount of the chemical, and if it is toxic, here is an ideal way of becoming poisoned.

* Received for publication Oct. 27, 1926.

Symptoms

The patient has a variety of complaints which may be summarized as follows:

1. A feeling of impending quinsy.
2. A peculiar feeling of chilliness in the chest and not in the extremities, which occurs chiefly in the morning on rising.
3. A feeling of "electricity" in the chest.
4. Morning nausea.
5. A feeling of heaviness in the upper abdomen when lying down.
6. Wandering pains in the shoulder and left leg.
7. Constipation.
8. Slight cough.

The pain in the throat, the heaviness in the stomach, and the feeling of chilliness are the symptoms on which he lays most stress.

He has had these symptoms for nearly five years and has seen many physicians and has submitted himself to many examinations, both physical and laboratory, without obtaining relief. His tonsils were removed but the feeling of quinsy still persisted. He has had several X-ray examinations of the chest and several barium meal examinations of the gastro-intestinal tract, but nothing has been found to account for his symptoms.

Physical Findings

Repeated physical examinations have shown the patient to be of good physique and nutrition, weighing about 165 pounds, but looking noticeably pale (described by one physician as cachectic). The pupils reacted to light and accommodation. The teeth were in rather poor condition; there were a few old roots but no gold crowns nor pyorrhea. The throat was clear (tonsils have been removed). The larynx on examination by laryngoscope appeared to be healthy. The chest was negative by repeated examination and by X-ray. The heart appeared to be in good physical condition as demonstrated by stethoscope before and after exercise, and by fluoroscope. The blood pressure at various times ranged from 142/90 to 128/88. There was possibly some thickening of the peripheral arteries. The physical examination of the abdomen and also the X-ray examination following barium gave negative findings. On rectal examination the prostate was possibly enlarged slightly (the patient urinates once during the night). The genitalia were negative. The lower extremities showed a few old scars over the tibiae and a few varicose veins but were otherwise negative. There was no edema. The examination of the nervous system showed no impairment of the reflexes or of sensation.

Laboratory Findings

Blood.—Three separate examinations of the blood gave the results shown in Table 1. The red blood cells were normal in size and shape.

Urine.—On repeated clinical examination the urine was practically negative. Hyaline casts were reported twice but no albumin, and the specific gravity has been good.

On Dec. 13, 1924, *traces of tin* were reported in both the urine and the feces. In January, 1925, the urine and the feces were again reported positive for tin in minute amounts. Other urines tested to control the method were negative.

On Nov. 30, 1925, a final examina-

tion of stool and urine was negative for tin.

TABLE 1.—RESULTS OF BLOOD EXAMINATIONS

RED BLOOD CELLS	WHITE BLOOD CELLS	HEMOGLOBIN	NEUTROPHILS	LYMPHOCYTES	TRANSITIONALS	EOSINOPHILS
no.	*no.*	%	%	%	%	%
5,000,000	5,000	77	74	22	4	..
5,300,000	9,200	80	64	35	1	..
4,900,000	5,800	84	70	28	1	1

Discussion

The symptom-complex shown by this man might make one think of a neurosis and such might well be the diagnosis. His symptoms are not unlike those described by Jolles (1) and by Salzer (2), however, in connection with two cases of alleged tin poisoning.

Jolles' case was that of a young woman who had come to him complaining of severe pains in the legs and, according to Salzer, a feeling of coldness. On examination she was found to have a neuritis of the legs with paralysis, anemia, albuminuria, and quite definite emaciation. The symptoms were definitely aggravated after the wearing of silk stockings heavily impregnated with tin. The diagnosis of tin poisoning was made in this case as a result of the recovery of tin in appreciable amounts in the urine.

Salzer's case was even more extraordinary. His patient complained of chilliness, irritation or pain in the throat, and indefinite pains in the legs, arms, and head. The man was wearing a dental plate, the matrix of which was two-thirds tin and one-third bismuth. Tin was found in the urine, and also in the blood and stools. Approximately 5 gm. of the feces (dried) yielded 2.1 mg. of tin, and 13 c.c. of blood 1.5 mg. This case did not improve following the removal of the plate, but Jolles' patient, when she ceased to wear the silk stockings, slowly recovered.

A third case (3) is that of a chemist who inadvertently filled his pepper caster with putty powder (an impure oxide of tin). He continued to use it until he fell ill two months later. His symptoms are not reported but he ultimately died.

A diligent search of the literature has failed to reveal any similar cases. It is odd that this should be so, if the three cases reported were really cases of tin poisoning, for tin is a metal which has a very widespread use and one with which we come in contact every day. It is no secret that a great number of our foods are contaminated with tin to such an extent that large doses are quite often ingested. Street (11), for example, examined some few years ago a number of specimens of canned beans and found quantities of tin varying from 93 mg. to 630 mg. per kilogram of solid portions, and from 26 to 121 mg. per kilogram of liquid portions. Tin must, therefore, be a metal which we all ingest from time to time; if it is poisonous, it is strange that so few cases of chronic poisoning have been reported.

It is true, of course, that one man may be poisoned where a dozen re-

main healthy, and perhaps the usual salt of tin which we ingest is not toxic. It is also true, however, that the finding of an unusual metal in the urine or in the feces is by no means indisputable evidence of poisoning by that metal. We know that many painters and other lead workers excrete lead in the urine without showing any symptoms of poisoning. The same is true of mercury workers and, no doubt, of workers with other more or less toxic metals, such as zinc, for example, which is said to be quite constantly present in the excretions of many apparently normal individuals.

Literature

I have not attempted to review the literature of tin poisoning here; it is very considerable but not very important. A selected bibliography is appended for those interested in the subject.

As might be expected, the advent of canned goods some fifty years ago brought forth many articles on tin poisoning. In some of these articles tin was reported as contaminating the food; in others it was simply assumed to contaminate it. The usual argument was of the *post hoc ergo propter hoc* type—the patient ate food from a tinned container, and fell ill; therefore the case was one of tin poisoning. A few such articles are cited in the bibliography (4) (5) (6) (7). The rest of the bibliography is made up of articles in which a more or less serious attempt has been made to determine the toxicity of the metal. The general results seem to indicate that it is not toxic or is very slightly toxic in the form in which it is ordinarily found.

Tin Tetrachloride

There is no literature on the toxicology of tin tetrachloride. There was some thought of using it in chemical warfare on account of its irritating properties, and researches were carried on to determine its toxicity. The results of these researches were not published, so far as I know, and I am indebted to the courtesy of Dr. E. R. Hayhurst and the United States Bureau of Mines for the following information:

According to the Bureau of Mines, 8.5 parts of tin tetrachloride per million of air caused coughing in men. The fatal concentration for mice was found to be 1 mg. per liter for ten minutes' exposure.

My own investigations show that a concentration as high as 3 mg. per liter (reckoned as milligrams of tin tetrachloride) are well tolerated by guinea-pigs during ten minutes' exposure. With daily exposures to this concentration the animals show no evidence of poisoning beyond transient irritation of the nose and eyes. On the contrary, they thrive and gain weight over a period of months.

Conclusion

It is not unreasonable to assume that an individual who is suffering from unusual symptoms and who is excreting an unusual metal in the urine is being poisoned by that metal. But in the case of tin, which is such a common metal and one which we all ingest nearly every day, it does not seem reasonable to attribute poisonous

properties to it when only three cases of alleged chronic poisoning can be discovered in the literature.

Until other cases are added to the list, a verdict of "not proven" must be given.

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MANGANESE: THE FAILURE OF ITS ORAL ADMINISTRATION TO AFFECT THE HEALTH OF BIRDS*

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THE continued inhalation of manganese dust in the industries produces marked and persistent nervous symptoms pointing to central degenerative lesions. The phenomena are well described by Alice Hamilton (1) and by Gayle (2). These authors also cite the literature. Attempts to produce similar phenomena in animals have been unsuccessful, practically with the sole exception of the experiments of Mella (3) with monkeys which received intraperitoneal injections of manganese chloride during eighteen months. Long-continued oral and parenteral administration of manganese compounds to other mammals have produced either no effect or hepatic cirrhosis and fatty degeneration of the heart and kidneys (Reiman and Minot (4), Findlay (5), and Handovsky, Schulz, and Staemmler (6)). Handovsky and his collaborators observed acute paralysis promptly after the injection of large doses, but this is presumably a different phenomenon from the chronic poisoning. Findlay states that some of his animals that died after six to ten weeks showed rigidity of the limbs for some days before death; but this differs so much from the predominance of the nervous symptoms in the clinical cases that the identity of the phenomena appears doubtful. The occurrence of the visceral effects shows that the general absence of the nervous symptoms was not due to nonabsorption; moreover, Reiman and Minot showed directly the presence of manganese in the systemic blood for a short time after feeding manganese ore, although with oral administration a large part of the manganese is intercepted by the liver and excreted by the bile.

The virtual failure to produce the typical clinical phenomena in the ordinary animals made it advisable to attempt this on birds. Experience with experimental lead poisoning has shown that birds afford special advantages for chronic metallic intoxication, in that the grinding in the gizzard favors the solution of the metal; and that disturbances of health are promptly manifested by loss of body weight and by anemia. Birds also readily show nervous phenomena, as illustrated by rice disease and lead poisoning, although these are not of the central type of the clinical manganese complex.

Experiments on feeding manganese to pigeons, reported by Hanzlik and Presho (7), were without decisive

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results. However, their method of administration, as a single dose, was large piece of manganese (0.15 to 0.5 gm.) placed in the gizzard.[1] This

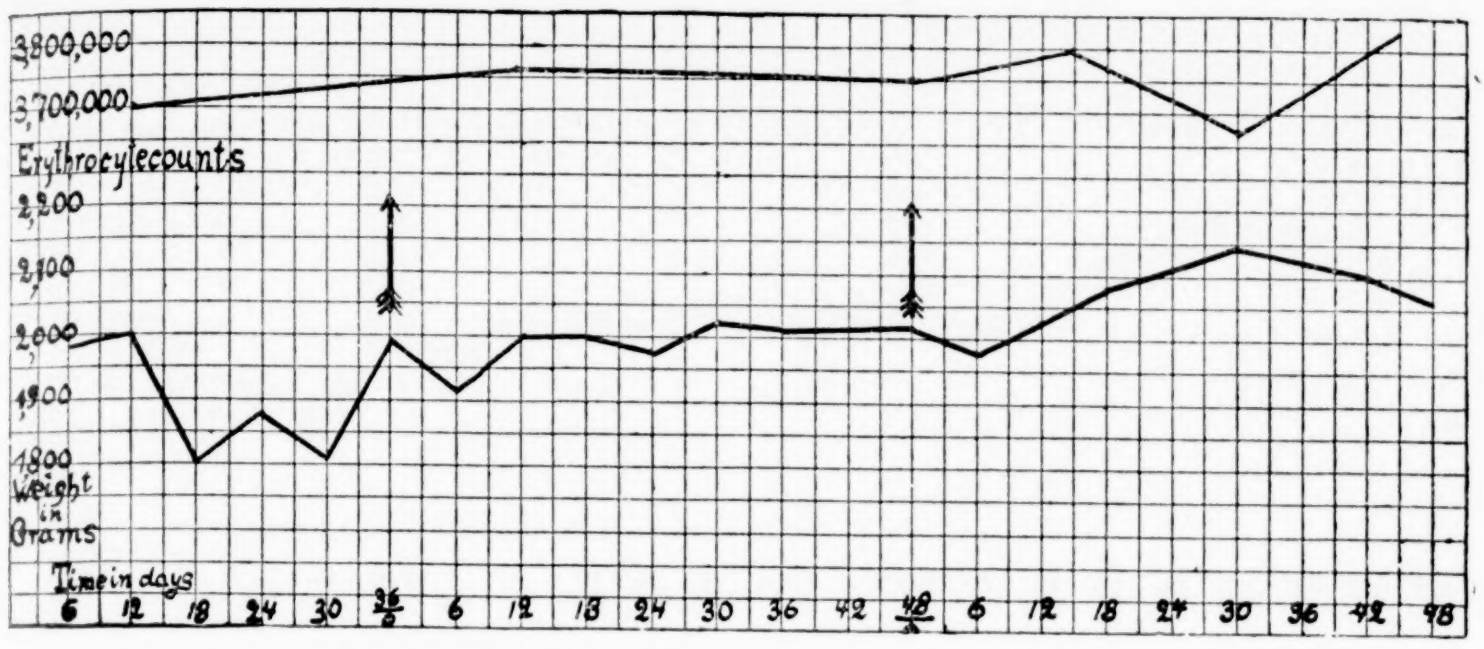

FIG. 1.—Changes in weight and in erythrocyte count (average of three pigeons). Thirty-six days after the beginning of the experiment (at the first arrow) a single dose of manganese (0.5 gm.) was administered; forty-eight days later (at the second arrow) the administration of manganese (0.2 gm.) every third day was begun.

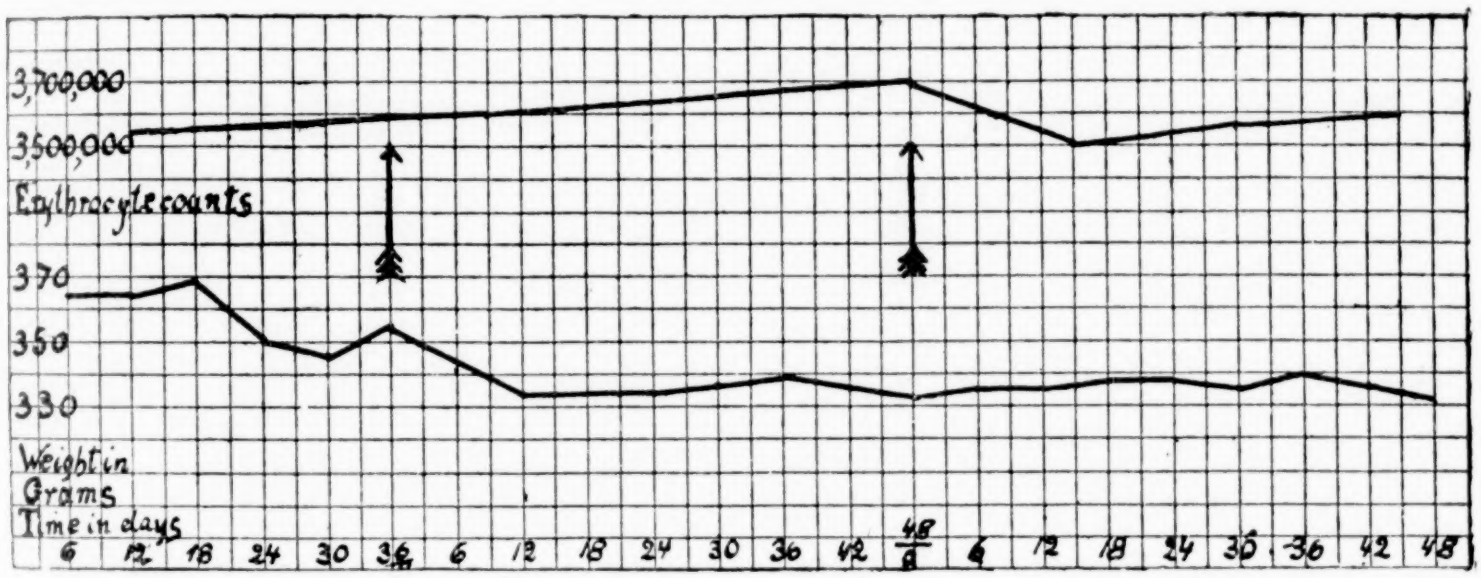

FIG. 2.—Changes in weight and in erythrocyte count (average of two roosters). Thirty-six days after the beginning of the experiment (at the first arrow) a single dose of manganese (1.5 gm.) was administered; forty-eight days later (at the second arrow) the administration of manganese (0.5 gm.) every third day was begun.

not suited to produce chronic poisoning, because, unlike lead, manganese dissolves readily in gastric juice (4), and therefore disappears in a short time from the alimentary tract. This we have confirmed by X-ray examinations which showed that no metal remained when birds were examined two and three days after having a early solution would militate against producing chronic poisoning by a single dose; therefore, when no effects were observed in forty-eight days after a single piece of 0.5 to 1.5 gm.

[1] We are indebted to Prof. T. W. Todd of the Department of Anatomy for these X-ray pictures.

was given, we resorted to continued administration, pushing the pieces of the metal (0.15 to 0.2 gm. for pigeons; 0.5 gm. for roosters) into the crop or the esophagus every third day, over a period of forty-five days. For the three pigeons used, the single dose of manganese averaged about 0.45 to 0.6 gm. per kilogram, the total dosage in the forty-five days 6.7 to 8.9 gm. per kilogram; for the two roosters, the single dose averaged 0.25 gm. per kilogram, the total dose 3.7 gm. per kilogram.

The curves of the weights and the blood counts are shown in Figures 1 and 2. The first arrow denotes the single massive dose; the second arrow, the beginning of the continued administration, which lasts to the end of the curve. It will be seen that there was no effect on either the weight or the blood count; nor did the animals show any nervous or other symptoms, although the observations were made for fourteen weeks, counting from the beginning of the three-day administration. It did not, therefore, seem worth while to continue the experiments.

The failure to produce in experimental animals the clinical symptoms observed in human beings might be due either to the fact that the human subjects were especially susceptible, or to the differences in the method of absorption, since the clinical cases invariably involved inhalation of manganese dust. The question might perhaps be answered by exposing experimental animals under similar conditions in the factories in which manganese poisoning is important. We lack, however, the opportunity to put this suggestion to the test.

Conclusion

The oral administration of large doses of metallic manganese to birds failed to produce any toxic effects.

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THE VENTILATION AND HEATING OF FACTORIES*

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ASSISTED BY
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Introduction

QUESTIONS relating to the ventilation and heating of factories have been the subject of a large amount of investigation in the past, but general unanimity as to the best methods is very far from being reached. For instance,there is a sharp conflict of opinion concerning the relative merits of natural and of artificial methods of ventilation, and the difficulty of the problem is increased by the fact that a given system which is found suitable for one country is not necessarily applicable to another country where the atmospheric conditions are different. Nevertheless it is possible to make allowances for the atmospheric conditions, and any careful investigation of factory heating and ventilation, whatever its country of origin, may yield information of general utility.

The investigation to be described was made by us in England, where the atmospheric conditions are usually milder than in America, as the air temperature does not fall below 20°F., or rise above 80°F., on more than three or four days a year, while temperatures below 10° or above 90° are practically unknown. In the course of our investigation, which lasted two years, we visited a large number of the most up-to-date factories known to us, and we made systematic observations, both in summer and in winter, at twelve of them. The factories tested were used for the manufacture of boots and shoes, tin canisters, machinery, polishes, and other articles.

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Natural Systems of Ventilation, with Occasional Artificial Extraction

It would be generally agreed that a natural system of ventilation is preferable to an artificial one if it can be so constructed as to yield the degree of air movement desired, not only on most days of the year, but on all days, whether the outside air be dead calm or blowing a gale. In a large workroom, however, it is practically impossible to secure adequate ventilation at all times by means of windows and skylights alone, and an extraction system must be added. If this takes the form of several openings in the roof, fitted with cowls or louvers, these openings often pull against one another, and currents of heavy cold air may pass down one or more of them, while currents of light warm air rise through the others. In any case, the extraction so effected may be quite inadequate for a large and crowded

workroom. Hence it is very desirable that extraction should be assisted by artificial means. At one large factory (boot and shoe), where there was a specially good system of natural ventilation combined with optional artificial ventilation, we spent some months in making a thorough survey. The factory had four floors, each main workroom being 280 feet by 46 feet in area, and $11\frac{2}{3}$ feet high. The sides of the factory consisted almost entirely of windows, and, in addition, the top floor had skylights looking due north. The exhaust ventilation was effected through four large trunks in the middle line of the building. In each trunk were four separate flues, one from each floor, which opened to louvers on the roof. They also connected with a large centrifugal fan on the roof, and either artificial or natural extraction could be employed at will. Outlet gratings from the workrooms to the exhaust flues were fixed at floor level, and 10 feet above it. The extraction system was found to be almost without influence in the summer, for 8 to 20 changes of air per hour were effected by the window ventilation alone. In the winter, however, when nearly all the windows were closed, the artificial extraction raised the number of air changes from 2.4 to 6 per hour. Extraction by natural means was ineffectual as it removed only a tenth as much air as extraction by fan, and sometimes the air currents in the flues were reversed.

The heating systems associated with natural ventilation systems almost always take the form of pipes or radiators, which are supplied with hot water or steam. At the factory in question there was an elaborate low pressure hot water system, which supplied radiators fixed near the floor, under the windows. From them convection currents of warm air constantly ascended in winter time. The usual method of warming the fresh air entering from the outside was by means of Tobin tubes. These tubes, 2 feet in width and 8 feet in height, were connected both with the air outside and with the workroom itself by dampers at floor level. They contained hot water radiators which warmed the entering air, but in cold winter weather it was usual to close all the outside dampers, so that the air was sucked from the room.

Though several other factories visited by us were heated by radiators, a pipe system was more frequent, and this almost always took the form of overhead steam pipes. These pipes were generally about 8 feet above floor level. We have no doubt that systems of heating by overhead steam pipes are radically wrong, for the larger portion of their heat ascends to the roof and is wasted, while only a small portion reaches the workers below, and even then it reaches their heads rather than their feet. Overhead steam pipes are undoubtedly of great value in checking down drafts of cold air from skylights. Hence, in any workroom lighted by skylights it is desirable to have some overhead pipes, but they should be few in number, and should be placed for the specific purpose of checking down drafts, and not for the main heating scheme of the workroom.

Perhaps even better than placing the hot water pipes or radiators near the floor level of a workroom

would be to place them *under* the floor, and heat the whole of the floor material. The feet would then be kept pleasantly warm, while fresh air at a lower temperature could be admitted at head level. We have not heard of any factories heated on this system, except for one workroom which is described subsequently, but it has been used successfully in other buildings, *e. g.*, the new Cathedral at Liverpool.

Mechanical Systems of Ventilation and Heating

During the last twenty years or so the tendency has been more and more to ventilate by mechanical systems rather than by natural ones, as the mechanical systems are more readily kept under control. Moreover, in extremely cold weather, such as occurs more frequently in America than in England, it is very desirable to warm the fresh incoming air, and this can be done more easily by a mechanical system than by a natural one. The mechanical systems of ventilation employed in England are usually of the plenum type, and are combined with heating, for in winter time large volumes of hot air are driven into the workrooms through ducts and gratings. Associated with the plenum ventilation there is generally a good deal of window ventilation; in fact, we found that in some instances the ventilation was effected almost entirely by means of windows, the volume of hot air supplied being insufficient to produce more than a small change of air, though it was adequate for heating purposes. The plenum air is usually conveyed by overhead trunks, and discharged above the heads of the workers. At one factory we investigated seven workrooms, and we found that in winter time air at a temperature of 120° to 140°F. was discharged from the ducts with a velocity of 1,600 to 3,000 feet per minute. When the fan was turned on, it raised the velocity of the air currents in the rooms from 25 feet per minute to 30 feet; in another factory it raised the velocity from 32 feet to 36 feet. The volume of air driven into the rooms effected 1 to 6 changes per hour, apart from the changes produced by window ventilation. The ducts of the plenum trunks in these factories were 9 to 13 feet above floor level, but at some of the factories investigated by us the ducts were continued vertically downward to within $1\frac{1}{2}$ to 2 feet of the floor. The air discharged by them against the floor sometimes created noticeable air currents, and at one factory, where the ducts were 9 inches in diameter, the workmen standing in their neighborhood frequently complained of drafts about the feet. Also, the air currents raised dust from the floor to a distance of 12 feet from the inlets, and so it is evident that this system of air discharge at floor level is unsuitable for factories where dusty processes are carried on. At another factory, however, where the ducts were only 3 to 6 inches in diameter, there were no complaints by the operatives.

At one factory (boot and shoe), we investigated a rigid system of mechanical ventilation. None of the windows could be opened, and the whole of the air was supplied by a 10-foot propeller fan in the basement of the building. This drove air—which

was warmed in winter by passing it through a battery of steam pipes—through shafts which connected with ten inlets in each workroom (252 by 52 feet in size). Each inlet was 7 feet by $1\frac{3}{4}$ feet in area, and was situated in the middle line of the room, 6 feet above the floor. The air passing in was deflected horizontally across the room, and it escaped to other shafts by means of ten outlets, of the same size as the inlets. These were likewise situated in the middle line of the rooms, but were at floor level. The system provided 8 changes per hour, but the air in the rooms often smelt stale. It caused objectionable drafts in many parts of the workrooms, and the workers often stopped up the ventilators, though this deprived them of the warm air.

Temperature Gradients

It is obvious that, if the source of heat in a room is 9 feet or more above the floor, the temperature of the air at the head level of the workers will tend to be higher than at foot level; whereas, if the heating is on or near the floor, the difference of temperature at head and foot levels will be less. In order to determine the actual extent of the temperature differences induced by various systems of heating, we made systematic investigations, not only at foot level (6 inches above the floor) and head level (4 feet, 6 inches, or what is roughly the mean between the level of sitting and standing workers), but at still higher levels in most of the factories visited. In a room at one factory the hot air could be driven at will through a set of plenum ducts fixed 6 inches above floor level, or through another set fixed $9\frac{1}{2}$ feet above the floor. It will be seen from Figure 1 that when the

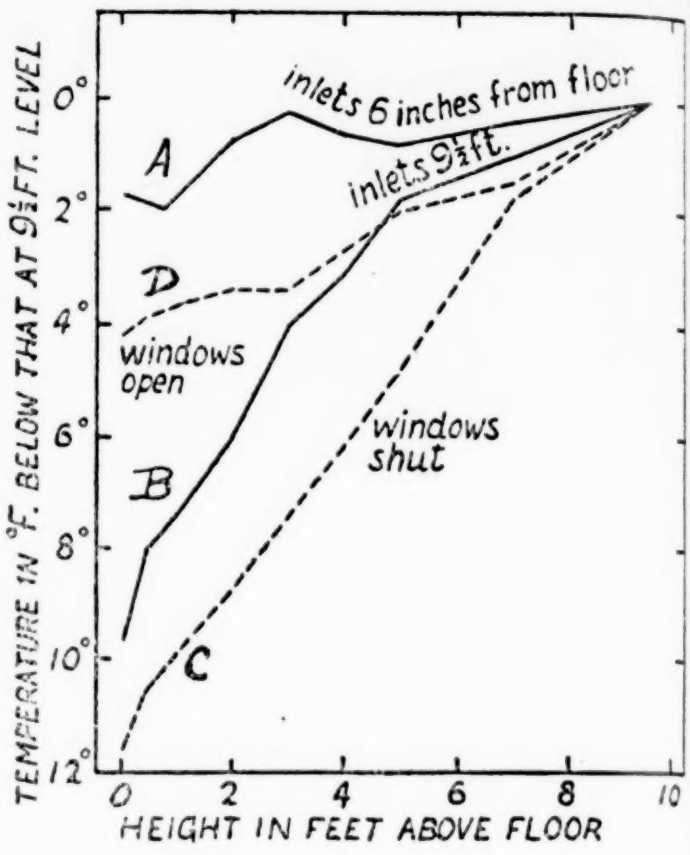

Fig. 1.—Effect on temperature gradient of altering position of plenum ducts, and of opening windows.

former set of ducts was in operation, the temperature at floor level was only 2°F. lower than that at the $9\frac{1}{2}$-foot level (curve A), but when the other set of ducts was turned on in addition, the temperature difference was nearly 10° (curve B). The temperature gradient is easily influenced by such a change of conditions as the opening of windows, and the dotted lines in Figure 1 show the results of observations made on another day when only the upper ducts were functioning. With all the windows shut a gradient of 11.6° was observed (curve C), but when the windows on one side of the room were opened, the gradient was only 4.2° (curve D).

The means of thousands of observations made in various factories at foot level and at head level are re-

corded in Table 1. It will be seen that workrooms heated by overhead steam pipes gave the worst result, and at outdoor temperatures of 40° to 49° the temperature at foot level was 4.2° lower than at head level, while at 30° to 39° it would probably have been more than 5° lower. With plenum systems the temperature gradient varied according to the height of the ducts above floor level, and when the ducts discharged the air on to the floor, the temperature at foot level was only 1.8° below that at head level. In one workroom the source of heat was below the floor, as it came from the boilerhouse underneath, and here the foot level temperature was only 0.9° lower than at head level. Hence there can be no doubt that the lower the position of the heating system, the less the temperature gradient. Steam pipes are specially bad because their temperature is usually much higher than that of plenum air, and so they heat the surrounding air more, and cause more rapid upward movements of hot air. The amount of energy wasted by overheating the upper strata of air in factories must be enormous. In addition, the wasted heat often indicates positive discomfort to the workers from cold feet, for a high temperature gradient above the heads of the workers is always accompanied by a rapid fall of temperature between head level and floor level.

TABLE 1.—SHOWING THE INFLUENCE OF THE SYSTEM OF HEATING ON THE TEMPERATURE GRADIENT IN FACTORIES VISITED

SYSTEM OF HEATING	NUMBER OF WORK-ROOMS IN-VESTIGATED	DEFECT OF TEMPERATURE AT FOOT LEVEL WHEN OUTDOOR TEMPERATURE WAS	
		30°–39°F.	40°–49°F.
		°F.	°F.
Overhead steam pipes	4	...	4.2
Plenum: 13 ft. above floor	4	5.1	4.1
Plenum: 9 ft. above floor	4	3.5	2.9
Plenum: or radiators, 5–8 ft. above floor	4	3.0	2.3
Plenum: discharging at floor	2	3.2	1.8
Both floor and overhead	6	2.0	1.3
Beneath floor	1	...	0.9

Cooling Power of the Air

The effects of the various systems of heating and ventilation on the cooling power of the air, as estimated by means of the dry kata-thermometer, were determined systematically both in summer and in winter. We obtained fairly complete series of data in twenty workrooms, and in Table 2 these data (head level observations) are averaged. From the observations made in the best ventilated factories we concluded that it is possible, under most conditions, to attain the results shown in the lower half of the table, and we see

that the ideal cooling powers suggested, for light industrial work, range from 7 in cold winter weather to 6 in hot summer weather, while the air velocity ranges from about 30 feet per minute in winter to 100 feet in hot summer weather.

It should be remembered that the suggested cooling powers apply to England and not to America. The observations of Yaglou (1), Houghten, and others (*cf.* (1)) on the comfort zone and on effective temperature show that the numerous subjects examined preferred a temperature quite 5° higher than that considered comfortable by English subjects. One of us (2) attributed this fact to Americans being acclimatized to hotter summer weather than that experienced by English people, while in winter time Americans heat their buildings more than the English do, and are therefore acclimatized to a higher winter temperature. However, the American subjects of experiment appear to have been mostly sedentary individuals such as office workers, and not factory operatives as ours were, and this may account for part of the difference. In any case, the principle of a slightly graduated cooling power at different seasons of the year is the same, though further experience may show that, owing to the higher temperatures preferred in America, the most suitable cooling power may be about 6 in winter and 5 in summer.

TABLE 2.—THE MEAN COOLING POWER OF THE AIR IN TWENTY WORKROOMS

		OUTDOOR TEMPERATURE (°F.)				
		Under 40°	40°–49°	50°–59°	60°–69°	70° or more
Actual observations	cooling power	6.8	6.7	6.4	5.7	4.5
	temperature (°F.)	60.3	62.0	64.4	68.6	76.2
	velocity (ft. per min.)	22	25	30	36	51
Practicable ideals	cooling power	7.0	6.9	6.8	6.5	6.0
	temperature (°F.)	61.6	62.0	63.6	67.9	74.6
	velocity (ft. per min.)	29	30	35	50	100

On an average, the air in the factories investigated by us had a relative humidity corresponding to 60 per cent. saturation, both in winter and in summer.

In order to ascertain the adequacy of the heating and ventilation at a factory, and the extent to which it can be remedied without having recourse to structural alterations, it is necessary to determine systematically not only the cooling power of the air (with its temperature and velocity components), but also the ventilation area, and the extent to which it is utilized. We noted the number and size of the windows and the extent to which they could be opened, and also the other openings such as louvers in the roof, loading doors, etc., and we calculated the ventilation area in terms of square feet per 100 square feet of floor area. We found that the twenty workrooms investigated had a ventilation area

varying from 0.7 to 14.8 square feet per 100 square feet of floor area, the average being 5.5 square feet. Of this area, the following amounts were kept open, on an average, at various outdoor temperatures:

Outdoor Temp. °F.	*Window Area Open* %
30–39	4
40–49	10
50–59	34
60–69	53
70–79	73

Variability of the Air Currents

It is often maintained that the air in plenum ventilated workrooms feels more stagnant and oppressive than that in naturally ventilated rooms. In order to investigate the validity of this hypothesis, we made observations on air movement in a large number of rooms, with and without the fan running. The investigators first noted down the sensation of air movement experienced, according to the scheme described in This Journal (2). The cooling power was next ascertained, and this was followed by determinations of the variability in the velocity and temperature of the air currents. In order to measure the variability, special apparatus was designed by one of us, in conjunction with J. J. Manley (3). The air movement was tested by means of a hot-wire anemometer, which consisted of a "detector" composed of three thin platinum wires fixed in three planes at right angles, and supported on an ebonite ring so as to catch air currents moving in all directions. The wires were heated to about 130°C. by the current from an accumulator, and they formed one arm of a Wheatstone bridge, the other arms of which were composed of Eureka wire (which has no temperature coefficient). One of these resistances was adjustable, whereby the resistance of the hot wire could be balanced. Connected with the bridge was a Paul unipivot deadbeat galvanometer, and a shunt. The galvanometer was read at intervals of two and one-half seconds, synchronous with the ticks of a metronome. The apparatus was calibrated by placing the detector in a small wind tunnel.

The oscillations in the temperature of the air were measured by means of a thermopile consisting of twenty junctions of iron and nickel wire. These junctions were hammered out very thin, and the wires were fixed in a boxwood ring so that they might catch air currents from all directions. The ring could be pushed down so as to fit tightly in an annular trough, which prevented access of air to the lower junctions. The thermopile was connected with a second galvanometer similar to that above mentioned, and this was read by a second observer synchronously with the other instrument.

The kind of result obtained with these instruments is indicated in Figure 2. In the first pair of records (*a*), the oscillations of air velocity and temperature are somewhat larger than the average. It will be seen that they usually synchronize, rise and fall of velocity (due chiefly to drafts of cool air from open windows) being accompanied by fall and rise of temperature. In (*b*) the oscillations are smaller than usual, and do not synchronize.

Some hundreds of observations were

made under various atmospheric conditions, and the results obtained are recorded at length elsewhere (4)

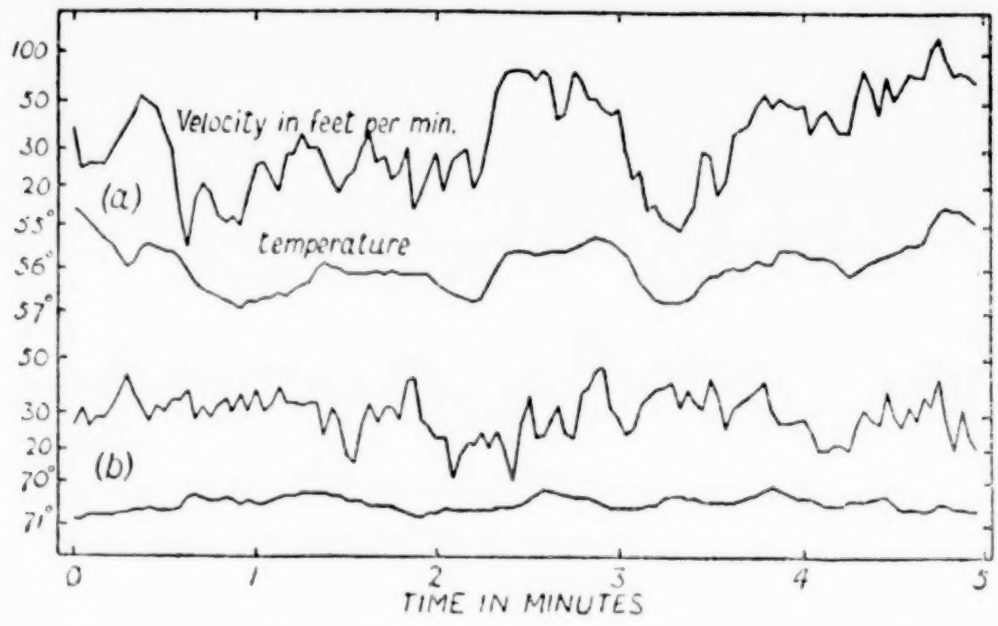

FIG. 2.—Oscillations in the velocity and temperature of the air in factories.

(5). We found that the sensation of air movement experienced increased to a moderate extent with increase in the oscillations of air velocity, but no clear proof was obtained that oscillations of temperature increased the sensation. Rather to our surprise, we found that the oscillations of velocity and temperature were no greater in factories ventilated by natural systems than in those ventilated by mechanical systems, but the natural ventilation systems did cause a subjective sensation of rather more freshness in the air than did the plenum systems. At the same time they kept the air slightly more humid.

INFLUENCE OF VENTILATION AND HEATING ON HEALTH

The real significance of various systems of ventilation and heating must be sought in their influence on the health and efficiency of the workers who have to experience them. The most reliable information we were able to obtain on the subject was drawn from observations in six workrooms at a canister factory. There were about 140 women and girls in each room, or 809 altogether, and we were able to obtain regular records of the time lost from sickness, as distinct from that lost by other causes, for a period of two years. From Table 3 it will be seen that on an average the amount of time lost in the different rooms varied from 1.47 to 2.05 per cent. of working time. The time appeared to depend more especially on the temperature of the air, for it was nearly the same in rooms *a* to *d*, which had a temperature of about 62°F. in winter and 68°F. in summer. Taking the mean loss of time in these rooms as a standard, we found that in room *e*, which was 7° colder than the average in winter, the sickness showed a 21 per cent. excess, while in room *f*, which was at all times about 7° warmer than the average, it showed a 32 per cent. excess. Hence it appears that a medium temperature is best for health, and that a departure from it in either direction tends to cause increased sickness.

The New York State Commission (6), in its investigation of the health of schoolchildren in America, came to the conclusion that the children who attended schools with window ventilated classrooms kept at a temperature of about 59°F. suffered from respiratory diseases to about the same extent as the children in window ventilated rooms kept at 66.5°; but children in fan ventilated rooms at 68.5° showed a considerable excess, for 70 per cent. more suffered from colds, etc., while 18 per cent. more were absent. Hence these results agree with ours in indicating the evil effect of too high a temperature; though quite apart from any question of temperature, it may be that mechanical systems of ventilation are less healthful than natural ones. The Commission even states that "the avoidance of overheating is the primary essential," while "air change, direction of flow, and all other factors are secondary."

In another factory which, like the canister factory, was ventilated by an overhead plenum system, we obtained evidence which seemed to point to ventilation as the chief factor influencing the health of the workers. In two of the rooms the girls employed were engaged on exactly the same occupation of tying up small packages, and yet their sickness rate was very different. During a two-year period the average lost time was 3.73 per cent. and 2.44 per cent. respectively. The cooling power of the room with the lower sickness rate was rather greater than the average, while that in the other room was distinctly less, almost entirely because of the low air velocity. This averaged only 15 feet per minute in winter and 27 feet in summer, while in the healthier room it was 34 feet and 40 feet respectively.

TABLE 3.—TIME LOST BY SICKNESS AMONG 809 WOMEN EMPLOYED AT A CANISTER FACTORY

WORKROOM	MEAN WORKROOM TEMPERATURE		MEAN AIR VELOCITY		MEAN COOLING POWER		TIME LOST BY SICKNESS
	Winter	Summer	Winter	Summer	Winter	Summer	
	°F.	°F.	*ft. per min.*	*ft. per min.*			%
a	59.8	66.2	40	47	7.9	6.6	1.47
b	63.0	67.2	32	37	6.8	6.0	1.51
c	61.3	71.7	25	38	6.8	5.2	1.60
d	62.5	68.7	21	28	6.3	5.5	1.64
e	54.3	65.9	27	28	8.5	6.0	1.88
f	67.1	77.9	35	33	6.0	3.7	2.05
Mean.....	61.3	69.6	30	35	7.0	5.5	1.69

(61.7 for *a*–*d*; 68.5 for *a*–*d*; 1.55 for *a*–*d*)

Conclusions

In the heating of factories it is important that the source of heat should be as near floor level as possible, in order to reduce the temperature gradient to a minimum. Thereby the

feet of the workers are kept relatively warm, and their heads relatively cool, while there is an enormous saving of heat.

In England—with its mild climate—it is possible to ventilate large factories excellently by means of windows, coupled with the occasional use of artificial extraction.

The health of the workers reacts considerably to moderate changes of factory temperature and ventilation.

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SUMMARY OF THE NATIONAL SAFETY COUNCIL STUDY OF BENZOL POISONING*

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Introduction

THE Committee on Benzol[1] was organized as a result of a discussion of the hazard involved in the use of the solvent in question which was presented at the 1922 National Safety Congress held in Detroit. The work of the Committee was made possible through the appropriation of $5,000 by the National Bureau of Casualty and Surety Underwriters; through the assignment by the Surgeon-General of the United States Public Health Service of Dr. Leonard Greenburg to work on the problem for almost a whole year; through the loaning of professional personnel for shorter periods by the Massachusetts State Board of Labor and Industries (Mr. John R. Dexter) and by the Hood Rubber Company (Dr. J. N. Shirley); and through assistance or materials furnished by the Aetna Life Insurance Company, by Dr. N. B. Herman of Johns Hopkins University, by the Yale School of Medicine, and by the Weirton Steel Company.

Progress reports of the Committee were presented at the Buffalo Safety Congress in 1923, the Louisville Safety Congress in 1924, and the Cleveland Safety Congress in 1925. The final report of the Committee was published in May, 1926, as a pamphlet of 128 pages for the Chemical and Rubber Sections of the National Safety Council by the National Bureau of Casualty and Surety Underwriters.

Before considering in detail the conclusions of the Committee it seems desirable to bring out two points in regard to its activities which seem to the writer to be of somewhat more than passing significance.

The first point which may be noted is that we have here a somewhat exhaustive study of an industrial poisonous hazard which has been conducted primarily by and for an organization representing industry itself. It is true that the United States Public Health Service, the Massachusetts State Board of Labor and Industries, and the universities have generously co-operated in the task. Yet the initiative for the whole study has come from the National Safety Council, a group of industrialists federated for the safety of the worker on the ground that the human element is a primary factor in production; and the fact that this body

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[1] C.-E. A. Winslow, Chairman, Leonard Greenburg, Vice-Chairman, W. S. Paine, Secretary, H. Bradshaw, J. W. S. Brady, A. C. Fieldner, C. F. Horan, L. E. Weber, and J. M. Weiss.

with its long and splendid record of achievement in accident prevention should have now definitely entered the allied field of industrial poisoning is cause for profound satisfaction. In Europe the whole program of industrial hygiene is essentially a governmental one. In the United States, on the other hand, a major part of what has been accomplished for industrial safety and sanitation has been accomplished by the initiative of broad-minded employers of labor. This benzol study is a new demonstration of the readiness of industrial leaders to learn the facts and then to apply all available knowledge to the promotion of health and efficiency.

Next, I would call your attention to what I believe to be a second somewhat notable fact about this investigation—the method by which it was conducted. Nearly all previous work on industrial poisons has been of what may be termed a qualitative type. It has dealt with a relatively small number of instances of poisoning which have come, one by one, to the notice of physicians, and such cases, from the nature of the situation, have been as a rule of a more or less aggravated type. In this benzol study there has been for the first time a conscious and definite effort to pick out a representative group of apparently normal workers in a given industry and to make a quantitative study of:

a. Mechanical conditions affecting a possible poison hazard;

b. Analytic data indicating the degree of atmospheric pollution by the poison in question; and

c. Physical findings including delicate chemical, microscopic, and physiologic tests suitable for the detection of latent and incipient damage to the human body such as threatens the subsequent development of active clinical disease.

Since this benzol study was made, two other investigations in this country have been conducted along essentially similar lines—the work of the United States Public Health Service on tetraethyl lead, and the work on spray coating by the Pennsylvania State Bureau of Labor and by the Committee on Spray Coating of the National Safety Council. These three studies, all involving the principles outlined above, seem to the writer to embody a relatively new and highly promising contribution to the technic of industrial hygiene.

With these preliminary remarks we may proceed to a summary of the main conclusions reached by the Committee on Benzol; the body of supporting evidence must be sought in the full report of the Committee itself.

Chemistry of Benzol

Benzol or benzene (C_6H_6) is a colorless liquid, boiling at about 80°C.,[2] obtained from the distillation of coal tar and from the strippings of coke oven gas. It is highly insoluble in water, slightly soluble in alcohol, and completely miscible with ether, acetic acid, carbon disulphide, and a large number of organic substances.

[2] The usual figure given in the textbooks is 80.2°; but it may be noted that a sample of very pure benzol analyzed for the Committee showed that 70 per cent. of the material came off between 79.5 and 79.9°. The International Critical Tables prepared by the National Research Council give 79.6°, which is undoubtedly correct.

There are many substances commercially known as "benzol," some of which contain benzene, while others do not. All of them are, of course, to be sharply distinguished from benzine which is a petroleum product (a mixture of C_6H_{14} and C_7H_{16}).

Benzol was discovered by Faraday in 1825 in the liquid produced by the compression of illuminating gas obtained from certain oils. In 1865 Kekulé announced its structural formula. Mansfield studied its commercial production from coal tar in 1849, and twenty years later Caro Clemen and Engelhorn patented a process for its recovery from illuminating gas. Only, however, with the work of Carves, of von Hüssener, and of Brunck on the production of benzol from coke oven gas, between 1884 and 1887, did this substance come to play a really important part in industry.

Industrial Uses of Benzol

The commercial uses of benzol grew gradually and steadily from 1890 to 1915; but the development of benzol production during the war in connection with the manufacture of explosives led to an increase in the manufacture of benzol which has in turn opened the way for a rapid broadening of the field for the commercial uses of this substance.

In considering the practical problem of the use of benzol in industry it is important to remember that two very distinct types of processes are involved. In such industries as (*a*) the distillation of coal and coal tar in the production of benzol, (*b*) the blending of motor fuels, and (*c*) the chemical industries, including oil extraction, dye and dye intermediates, manufacture of paints, varnishes, and stains, and of paint and varnish removers, benzol is used in large quantities, but the very nature of the industry demands that it be kept in a closed pipe line system, any openings representing a loss of valuable vapors, and making the system an inefficient one with a correspondingly large financial loss.

In a second group of processes represented by the use of benzol (*a*) in the rubber industry, (*b*) in artificial leather manufacture, (*c*) in sanitary can manufacture, (*d*) in dry cleaning, and (*e*) in connection with the handling of paints, varnishes, and stains, benzol is employed chiefly as a solvent or a vehicle, and as a part of the process it must be removed so as to leave the originally dissolved substances in place. The method of removal of the benzol is usually to permit it to evaporate; in most cases this is done in the cold, in some cases, however, the compound may be warmed—a procedure which naturally removes the benzol with greater rapidity.

Benzol Poisoning

As in the case of many other toxic substances used in industry, benzol poisoning exhibits itself in two quite distinct forms, acute and chronic, according as exposure is brief and intense on the one hand or moderate and prolonged on the other.

Acute.—Occasional instances of acute benzol poisoning may be found in medical literature extending back to 1862. In our review of the litera-

ture for both Europe and America we have obtained a record of over 100 cases of acute benzol poisoning, of which about one-half were fatal (excluding a series of Russian cases complicated by hysteria).

Acute benzol poisoning generally occurs in one of two ways: either (*a*) by the sudden discharge of vapors through the failure to regulate a condensing apparatus or through the occurrence of a leak in piping in the vicinity of stills and other forms of chemical apparatus; or (*b*) by the entrance of workmen into tanks or other confined spaces in which benzol has been stored or used.

The common symptoms of acute benzol poisoning are: (*a*) dizziness, faintness, and drowsiness, culminating in unconsciousness and coma; (*b*) pallor of the face and cyanosis (blueness) of the lips and finger tips; (*c*) feeble and rapid pulse; (*d*) breathlessness and a feeling of tightness in the chest, sometimes culminating in immediate death from respiratory paralysis; (*e*) visual disturbances, with nervous excitation, tremors, and convulsions, and more rarely mania or delirium; (*f*) reddish spots on the skin and internal surfaces due to small hemorrhages in the tissues; and (*g*) where the substance has been taken in by the mouth, symptoms of acute gastro-intestinal irritation.

Death may occur within five minutes after exposure or the patient may apparently recover and succumb several days later. There appear to be marked individual variations in susceptibility to benzol; and the effects of a given atmospheric condition may probably be increased by vigorous muscular exertion, as suggested by the fact that a man first rendered unconscious by the inhalation of benzol vapors may often recover while those overcome while engaged in rescuing him may die.

The treatment of acute benzol poisoning involves, first of all, prompt restoration of the respiratory function by artificial respiration.

Chronic.—Chronic benzol poisoning, resulting from continuous or repeated exposure to benzol fumes in concentrations too low to produce marked narcotic effects is, of course, a condition much more obscure, and much more likely to be overlooked, than is acute poisoning. It is particularly likely to occur in the second group of industries alluded to above, in which benzol is used as a solvent and to a greater or less extent evaporated into the air of the workroom. Chronic benzol poisoning was first described by Santesson, in 1897, in workers in a rubber factory in Uppsala, and was first reported in the United States by Selling in 1910, as occurring in the coating room of a tin can plant.

The more commonly observed symptoms of chronic benzol poisoning may be summarized as follows: (*a*) general systemic disturbance as evidenced by headache, dizziness, weakness, loss of appetite, and loss of weight; (*b*) pallor, shown by blood examination to be due to true anemia; (*c*) marked reduction in white blood cells (revealed of course only by microscopic examination); (*d*) bleeding from nose, gums, vagina, and bowels, with the development of purplish spots caused by small hemorrhages within the tissues; (*e*) sore and spongy gums, and burning of eyes

and throat; (*f*) shortness of breath and tightness of chest; (*g*) sometimes, abdominal pains, nausea, and vomiting; (*h*) sometimes, slight tremors, visual disturbances, and abnormal sensitiveness to touch; rarely, convulsions and delirium; (*i*) rarely, rashes and skin eruptions.

Detection of chronic benzol poisoning in its early stages, with prompt removal from exposure, generally leads to complete recovery. If the case of chronic poisoning be a severe one, however, certain of these symptoms may persist for a long time after exposure has ceased; and nearly one in five of the cases reported in the literature has ended fatally.

Toxic Action of Benzol

Benzol introduced into the body (which in practice ordinarily occurs as a result of the inhalation of its fumes) exerts three more or less distinct major effects on the body. It plays the part of an anesthetic or narcotic leading to dizziness, faintness, and coma. It is at the same time, however, a nerve irritant producing characteristic spasmodic movements, and actual damage to nerve tissue. Coma and death may also result from this neurotoxic action as well as from the narcotic action of benzol. Above all, however, this substance possesses a definite and specific destructive power for the blood cells and for those organs which produce these cells. Herein lies its most universal and most characteristic effect.

Effect on Blood Cells.—At first there may be a slight increase in white blood cells but this is really due to a destruction of the white cells in the circulating blood, overbalanced by the compensatory production of more white cells by the blood forming organs (the lymph nodes, spleen, and bone marrow). This condition is exceedingly transient, however. Very shortly the blood forming organs themselves are injured, particularly in respect to their power to produce the special kinds of white cells known as polymorphonuclear leukocytes and lymphocytes. The total white cell count falls rapidly, producing the condition known as leukopenia. The tissues which produce the red cells of the blood are less readily affected and a normal or increased red cell count may persist for some time, parallel with a great decrease in white cells. Ultimately, however, the blood forming organs are so seriously damaged that the number of red cells, too, falls off, producing a pronounced anemia.

A decrease in the white cells of the blood is therefore the first indication of early chronic benzol poisoning, and the effect is so familiar that benzol has been used therapeutically for the treatment of diseases characterized by an excessive concentration of white blood cells. Our studies indicate that a fall from a normal value of 7,500 to 9,000 white cells per cubic millimeter of blood to 5,600 or less may be taken as a fair index of the presence of this disease. Of course, conditions other than benzol poisoning may cause leukopenia, but with a history of exposure to benzol and in the absence of symptoms of certain acute communicable diseases or of certain other industrial intoxi-

cations which may be associated with leukopenia, the diagnosis may be made on this basis with reasonable accuracy. This reduction in white cell count generally precedes any other symptoms of benzol poisoning and may therefore exist in persons who would be considered normal by the ordinary clinical tests.

The seriousness of benzol leukopenia is emphasized by the observations made by a number of investigators that resistance to pneumonia and other bacterial infections is greatly reduced by such a condition.

Extent of Benzol Poisoning in American Industry

In order to gain some idea of the extent of the benzol hazard in American industry we sent out a questionnaire in 1923 to a group of 324 industrial establishments which, from the nature of their products, might be expected to use benzol. Of these establishments, 140 replied; and, of the 140, eighty-four were found to be making use of this substance in greater or less amount. The largest amounts of benzol were apparently used in the chemical industries, in the can seal industry, in the rubber industries, and in the manufacture of artificial leather, but in the chemical trades the material is generally used in enclosed processes and the number of employees exposed is small.

From the results of this questionnaire and from our subsequent field studies made in 1924 we collected a list of fifteen fatal and eighty-three nonfatal cases of benzol poisoning occurring during the years immediately preceding. Out of twenty-three establishments in which ten or more persons were exposed to benzol, eleven, or nearly half, reported cases of poisoning, while of six plants in which fifty or more employees were exposed, all but one had had cases of poisoning.

During the last year of our work we made no attempt to extend this survey of the extent of the benzol hazard; but at least seven fatalities from this cause were brought to our attention during the first nine months of 1925; and during the five years ending June, 1925, there were in the state of Ohio, alone, twenty-nine cases of benzol poisoning, so obvious as to receive the benefits of industrial compensation.

It is therefore clear that the hazard of benzol poisoning in American industry is a serious one and constitutes one of the major problems of industrial hygiene.

Field Study

Conditions in Industries Employing Benzol.—In order to determine the actual extent of the benzol hazard under various industrial conditions, we selected, after a preliminary survey of industrial establishments, eighteen workrooms in twelve different plants for further intensive study. Most of these were rubber factories of various sorts, but dry cleaning, sanitary can manufacture, and artificial leather manufacture were also included.

The workrooms were studied from an engineering standpoint, with regard to the conditions under which the benzol was used and particularly the type of exhaust ventilation provided; analyses of the air were made under both summer and winter condi-

tions, in order to determine the extent of the resulting contamination of the atmosphere. For air analysis, we used the charcoal absorption method which gave us, not benzol alone, but the total content of solvent vapors. For convenience, however, the results have been expressed in terms of benzol. Whether other solvent vapors were actually present or not is of course indicated in each instance.

With small amounts of benzol in use and with no ventilation, or with general ventilation only (which our studies indicate is wholly inadequate to cope with the benzol problem), we found average concentrations of 100 to 1,360 parts of benzol per million parts of air. With large amounts of benzol in use, under similar conditions, we found average values from 340 to 1,800 parts per million. On the other hand, in plants using large amounts of benzol but with enclosed systems of local exhaust ventilation, we found averages only between 70 and 500 parts per million. The plant which had the most efficient systems of local exhaust gave us average values lying between 70 parts in summer and 90 parts in winter.

It appears from this study that some of the workrooms investigated at times approached the concentrations of benzol which have been found to cause acute poisoning (Lehmann states that 0.015 gm. per liter, or 4,700 parts per million,[3] may produce confusion in half an hour, and we found 2,640 parts in one individual analysis in a compound mixing room and 4,140 parts in a dry cleaning establishment). Five of the eighteen rooms gave average figures above the value of 550 parts which Legge found associated with clinical poisoning. On the other hand, with efficient local exhaust ventilation, and careful management of all details of the processes involved, it seems sometimes possible to use benzol in coating and mixing rooms, and in sanitary can manufacture, with an atmospheric pollution amounting to less than 100 parts of solvent vapors per million parts of air. Our next step was to determine whether this degree of protection was sufficient to avoid danger to health.

Extent of Early Benzol Poisoning

Results of Clinical Tests and Blood Examinations.—The crux of our problem was the examination of workers exposed to benzol under various industrial conditions, using the white blood cell count as our index of early benzol poisoning. We were ultimately able to make tests of this kind on eighty-one workers in the eighteen workrooms discussed above (see Table 1); and we found that twenty-six of the persons examined, or 32 per cent., showed clear evidence of blood cell destruction, as indicated by a white count below 5,500 (or in one instance a borderline white count of 5,800 with a very low red cell count). In seventeen instances the white count was below 5,000, in ten instances below 4,000, and in three instances below 3,000. In only ten instances, however, was the red cell count below 4,000,000. Control ex-

[3] The factor (313) for converting milligrams per liter of benzene into parts per million is taken from U. S. Bur. Mines, Tech. Paper 248, Table 8, p. 52.

amination of some fifty workers not exposed to benzol failed to show any such abnormal blood pictures.

The results of these blood examinations are distinctly disconcerting. Not only did about one-third of the

TABLE 1.—SUMMARY OF BLOOD FINDINGS IN EIGHTY-ONE WORKERS POTENTIALLY EXPOSED TO BENZOL

GROUP	ROOM	LOCAL VENTILATION	AVERAGE BENZOL IN AIR		BLOOD FINDINGS	
			Summer	Winter	Number Examined (81)	Number Positive (26)
			p.p.m.	*p.p.m.*		
Small amount of benzol used	150 B	−	100	...	9	2
No local ventilation I-A	60	−	150	...	1	0
Low benzol content in air	27 A	−	110	...	2	1
Small amount of benzol used	27 B	−	700	...	2	0
No local ventilation I-B	59	−	150	210	9	1
High benzol content in air	61 A	−	130	210	12	6
	61 B	−	1,360	580	1	1
Large amount of benzol used	78 A	+	70	90	0	0
Local ventilation II-A	150 A	+	90	...	1	1
Low benzol content in air	75 B	+	100	...	3	1
Large amount of benzol used	91	+	180	400	5	0[1]
Local ventilation II-B	50 B	+	.....	430	3	1
High benzol content in air	50 A	+	.....	500	4	1
	75 A	+	130	330	10	1
Large amount of benzol used	78 B	−	340	...	1	0
No local ventilation III	23	−	.....	...	6	2
High benzol content in air	83	−	620	...	9	6
	95	−	1,800	...	3	2

[1] Three clinical cases, one fatal since tests were made.

In only nine cases out of the twenty-six was it possible to obtain a fairly complete medical examination; and of these nine, five gave a history more or less clearly suggestive of chronic benzol poisoning (including two or more of such symptoms as headache, dizziness, pallor, loss of appetite, digestive disturbance, spongy gums, and nosebleed).

eighty-one workers exhibit clear evidence of early benzol poisoning, but, what is still more serious, the evidence of poisoning was clear even with good exhaust ventilation and low atmospheric contamination. In the group of workrooms using large amounts of benzol without local ventilation, ten out of nineteen workers gave a positive picture; in the group of

rooms where only small amounts of benzol were used without local ventilation, eleven out of thirty-six workers were positive. In the group using large amounts of benzol but with local exhaust ventilation, only five out of twenty-six workers were positive. Thus, local exhaust ventilation reduced the proportion of workers affected from nearly one-half to less than one-fifth; but even one-fifth remains a pretty high figure. Unfortunately we were unable (after repeated efforts) to make blood examinations in the can factory coating room which gave the best analytic results; but in a coating room with local ventilation, showing only 90 parts of benzol in the air in summer, the single worker exposed proved positive; and in a mixing room in an artificial leather factory, with only 100 parts of benzol in the air in summer, one out of three men proved positive.

We are forced to conclude that the control of the benzol hazard (except where the substance is used in completely closed systems) is exceedingly difficult; that, in practice, systems of exhaust ventilation capable of keeping the concentration of benzol in the atmosphere below 100 parts per million are extremely rare; and that, even when this is accomplished, there remains a decreased, but substantial, hazard of benzol poisoning.

Recommendations in Regard to the Use of Benzol

In Enclosed Systems.—As has already been pointed out, benzol is used in industry under two more or less distinct sets of conditions. In the manufacture of benzol from coal and coal tar, in the blending of motor fuels, and in the chemical industries, the solvent is necessarily handled in closed containers and pipe systems. Here, chronic poisoning is unlikely to occur and the chief hazard arises from acute poisoning due to carelessness in the cleaning of tanks, breaks in the apparatus, and similar accidents.

With regard to this type of process, it seems certain that with proper care in construction, maintenance, and operation the use of benzol can be made sufficiently safe to warrant its employment. It is true that fatal accidents have occurred, and will no doubt continue to occur, in these processes, just as such accidents occur, and will continue to occur, from the use of steam boilers. The danger is, however, in both instances a controllable one to be met by careful attention to safety provisions and not by the abandonment of the use of the substance or of the device in question.

The chief measures of protection which should be enforced in industries of this type are:

a. Regular and systematic inspection of apparatus to insure against breaks or accidental leakage.

b. The greatest possible care in freeing tanks or other receptacles which have contained benzol from all traces of the substance before they are entered for cleansing or repairing.

c. The protection of workers entering enclosed spaces liable to contain benzol fumes by the use of positive pressure air helmets or hose masks; and the conduct of all such work by

teams of two or more men who are familiar with the dangers involved.

As a Solvent.—In the rubber industry, in artificial leather manufacture, in sanitary can manufacture, in dry cleaning, and in the use of paints and varnishes, benzol is employed as a solvent or vehicle under conditions which, almost of necessity, permit more or less evaporation of the solvent into the atmosphere. Here, there is relatively little danger of acute benzol poisoning, but very great danger of chronic poisoning, arising from prolonged or repeated exposure to the fumes.

In order to minimize such hazards as far as possible, there are two general types of precautions which should be taken, tending respectively to decrease the degree of exposure and to detect and control incipient poisoning in its earliest possible stages.

1. To diminish exposure, enclosed processes should of course be used wherever possible and, whenever containers are cleaned or apparatus repaired, the special precautions discussed in the preceding section dealing with enclosed systems and the danger of acute poisoning should be observed. Wherever employees are likely in the course of their work to be exposed to benzol fumes, as in the ordinary solvent and evaporative processes or in handling the products of such processes, they should be protected by the most effective local exhaust ventilation designed according to the following general principles:

a. Where benzol is evaporated at room temperatures, air removal by local exhaust ventilation with down draft is recommended, although in certain enclosed processes direct ventilation (from the enclosure) with upward draft may be indicated.

b. Where localized heat is applied in the evaporation of the benzol, hoods or enclosures should be provided with up draft local exhaust. This draft should be sufficiently intensive and applied so closely to the point of origin of the evaporating benzol as to insure the complete removal of all of the benzol before the heated surface is removed from the hood or enclosure. This recommendation deals with specific processes where sufficient upward air movement is created by the heated surface to overcome the natural density of the benzol vapor.

Masks and respirators should not be relied upon to protect the worker against ordinary routine exposure to benzol fumes, since such devices cannot be made efficient without at the same time making them too uncomfortable to be worn continuously.

2. To detect incipient benzol poisoning at a stage when its effects can be minimized, it seems essential to the Committee that all workers to be employed in processes where exposure to the fumes of this solvent is involved should be given a thorough medical examination before employment and should be reexamined, with systematic blood counts, once a month thereafter. In addition to this routine reexamination, absence from work should be promptly followed up by some person conversant with the symptoms of benzol poisoning; and the employees themselves should be made familiar with the symptoms which are most likely to occur.

No worker should be employed

in a benzol process who shows signs of:

a. Organic disease of heart, lungs, or kidneys.

b. Hemorrhagic tendencies.

c. Anemia or any unusual blood picture.

Any worker who, on reexamination, shows any of the following symptoms should be promptly excluded from benzol exposure and transferred to some other department of the industry:

a. Hemorrhages from the mucous membranes of the nose, mouth, or other organs.

b. Decrease of more than the following amount from the employee's normal blood picture (normal conditions will be obtained from previous examinations of the individual employee): *white cells*, decrease of 25 per cent.; but in no case should an employee[4] with a white cell count of less than 5,000 be continued in benzol processes; *red cells*, decrease of 25 per cent.; *hemoglobin*, below 70 per cent.

Laboratory Study

Relative Toxicity of Benzol and its Higher Homologues

In view of the grave hazards involved in the industrial use of benzol we next proceeded to an experimental study of the relative toxicity of certain of the higher homologues of benzol in the hope that if such substances proved less dangerous they might be substituted in at least certain industrial processes.[5]

The results reported in the literature of the subject are somewhat conflicting, probably because of the uncertain composition of the materials used by certain workers and of the lack of clear discrimination between the various types of toxic action produced. In general, however, the more careful work has suggested that benzol is more dangerous than its higher homologues.

Our own investigation was conducted with adult white rats which were kept on a standard diet and subjected to preliminary study to determine the normal range of variation in the blood count of each animal. The substances used for our tests were four in number: pure benzol (boiling point 80°);[6] toluol (boiling point 111°); xylol (boiling point 139°); and Hiflash naphtha (boiling point chiefly between 165° and 185°). The influence of these solvents was studied in three different ways: by intraperitoneal injection; by subcutaneous injection; and by inhalation in a chamber specially arranged so as to make possible a close control of the proportion of solvent in the atmosphere.

Intraperitoneal Injection.—The method of intraperitoneal injection involves sudden exposure to a relatively intense effect of the injected substance. With benzol, all animals receiving as little as 0.5 c.c. per kilogram of body weight showed marked symptoms of a definite toxic action exerted primarily on the central nervous system, manifested by tremors, twitchings, loss of equilibrium, lack of response to stimulation, and ex-

[4] Reduction in white cells is the most important condition to be noted.

[5] This laboratory study was conducted by Dr. J. J. Batchelor of the Yale School of Medicine, Research Associate to the Committee.

[6] See footnote 2.

treme weakness. With doses in excess of 1 c.c. per kilogram of body weight the temperature of the animal dropped 3° to 8°C. At times paralysis of the extremities was practically complete. The animals always recovered from doses up to 1 c.c., but 2 c.c. per kilogram of body weight always proved fatal. It is of special interest to note that in the animals which recovered neither the white nor the red blood cell counts were materially affected. This is in accord with conclusions from the clinical study of human cases which indicate that acute and chronic benzol poisoning are quite distinct phenomena and that acute benzol poisoning, which is due to violent irritation of the nerve centers and consequent asphyxiation, fails entirely to produce the effect on the cell content of the blood which is characteristic of chronic poisoning.

The other three solvents studied—xylol, toluol, and Hiflash naphtha—when injected intraperitoneally, showed a wholly different picture. Xylol up to 0.75 c.c., and toluol up to 0.75 c.c. per kilogram of body weight, produced no symptoms whatever except slight apathy. Hiflash naphtha in doses of 0.5 c.c. produced some limpness and paresis and a lowering of body temperature. In larger amounts all these three substances produced deranged equilibrium and weakness, culminating in loss of power of movement and ultimately in complete narcosis with fall in temperature, but the effect in the case of toluol and xylol was relatively lacking in the symptoms of toxic stimulation of the nerve centers and was of the nature of a narcosis, rather than of a nerve irritation.

Subcutaneous Injection.—In view of the fact that the present study was concerned mainly with chronic poisoning, we have laid chief stress upon our subcutaneous injections. Here, doses of 1 c.c. per kilogram were injected under the skin of the abdomen or back (mixed with equal parts of olive oil to decrease local irritation and delay the rate of absorption). Injections were repeated daily for a period of four to twenty-two days. This mode of treatment leads to a gradual absorption of the injected substance, entirely comparable with what occurs in human cases of chronic industrial poisoning.

In the case of benzol it caused obvious constitutional symptoms, including apathy and weakness, loss of weight, and twitchings and tremors, indicating a toxic effect on the central nervous system and culminating in death when the injections were long continued. The white blood cells were promptly affected, the red cells more slowly, as in human clinical experience, and ultimately white cells almost disappeared from the blood.

On the other hand, the animals treated by subcutaneous injection with toluol, xylol, and Hiflash naphtha showed no constitutional symptoms whatever, aside from slightly lessened activity and slight loss in weight. The white cells were not permanently affected at all and the red cells suffered only a slight and transient reduction. The relative effects of the four solvents studied are summarized in Table 2.

Inhalation.—Finally, our inhalation experiments brought out the relative effects of the four solvents with even greater clearness. The results are summarized in Table 3.

We see from this table that, when animals were exposed for eighteen to twenty hours a day for seven days to high concentrations of benzol, toluol, and xylol, toluol and xylol were more toxic than benzol, since 1,600 parts per million of the former solvents proved fatal while 2,440 parts of benzol did not. This is due entirely to the narcotic influence of the solvents in question and is in accord with the general fact that narcotic action often increases with added methyl radicles. On the other hand, toluol

TABLE 2.—EFFECT OF INJECTION OF VARIOUS SOLVENTS

SOLVENT	DAILY SUBCUTANEOUS INJECTION OF 1 C.C. PER KILOGRAM OF BODY WEIGHT[1]				INTRAPERITONEAL INJECTION LETHAL DOSE
	Average Number of Injections	Average Loss in Weight	Average Reduction in		
			White Cells	Red Cells	
		%	%	%	*c.c. per kg.*
Benzol	13	26	91	28	1.25–2.0
Toluol	16	6	0	5	1.25–2.0
Xylol	10	3	0	10	2.00–2.5
Hiflash naphtha	11	4	0	5	2.5

[1] Five of the animals treated with xylol received 2 c.c. instead of 1 c.c. per day.

TABLE 3.—EFFECT OF INHALATION OF VARIOUS SOLVENTS

SOLVENT	HIGH CONCENTRATION[1]			MODERATE CONCENTRATION[2]			LOW CONCENTRATION[3]		
	Change in Weight	Reduction in White Cells	Symptoms	Change in Weight	Reduction in White Cells	Symptoms	Change in Weight	Reduction in White Cells	Symptoms
	%	%		%	%		%	%	
Benzol	−28	63	marked, neurotoxic	−14	81	moderate	−15	91	practically none
Toluol	−21	0	narcosis, death	−3	13	slight	+1	15	none
Xylol	−10	9	narcosis, death	−3	8	slight	+3	4	none
Hiflash naphtha	....	..	.....	−10	12	slight	−2	9	none

[1] Benzol 2,440 p.p.m.; toluol 1,600 p.p.m.; xylol 1,600 p.p.m.

[2] Benzol 815 and 1,035 p.p.m.; toluol 1,100 and 1,250 p.p.m.; xylol 980 p.p.m.; Hiflash naphtha 567 p.p.m.

[3] Benzol 460 p.p.m.; toluol 620 p.p.m.; xylol 620 p.p.m.; Hiflash naphtha 312 p.p.m.

and xylol even in this extreme concentration are almost without effect on the central nervous system or on the blood forming organs, both of which are seriously damaged by benzol.

In concentrations of 1,000 parts per million or less, the severe narcotic effects of xylol and toluol are practically absent and in such dilution the superiority of these substances as compared with benzol is most obvious. Even 460 parts of benzol damages the blood cell forming organs to such an extent as almost to eliminate the white cells from the blood and causes 15 per cent. loss in weight; while concentrations of 1,000 parts of toluol and xylol produce only slight effects either on cell count or on the weight of the animals.

It is this latter condition which is of importance from the practical standpoint of industry, since with their relatively high boiling points toluol and xylol would never be present in concentrations of over 1,000 parts except as a result of some temporary accident and, if they were, their irritant action would serve as an immediate and automatically effective danger signal.

Conclusion

Our field studies have thus indicated that the use of benzol as an industrial solvent is attended with health hazards which can only be avoided by the provision of elaborate local exhaust ventilation and by the maintenance of a comprehensive system of medical supervision.

On the other hand, our laboratory investigations make it clear that certain of the higher homologues of benzene, such as toluol, xylol, and Hiflash naphtha, are relatively free from the special hazards which attend the use of benzene itself. These substances, in large doses, are even more powerful narcotics than benzol, but their low volatility and marked odors make it highly unlikely that they will occur in workroom air in sufficient concentration to produce effects of this sort. On the other hand, they are almost wholly lacking in those specific destructive effects on the nerve tissue and, above all, on the blood forming organs so characteristic of benzol. Under ordinary conditions of use, and in any concentrations in which they would be likely to occur in workroom air, these substances appear to be relatively harmless.

We would therefore urge that the serious attention of manufacturers now using benzol should be given to the possibility of substituting one of these substances, or other relatively harmless substances, wherever the conditions of a given manufacturing process make it possible to do so.

BOOK REVIEW

INDUSTRIAL SAFETY ORGANIZATION FOR EXECUTIVE AND ENGINEER. By *Lewis A. DeBlois*, S.B., Director, Safety Engineering Division, National Bureau of Casualty and Surety Underwriters. Past President, National Safety Council. Member, Committee on Safety and Production, American Engineering Council. First edition. Cloth. Pp. xiii, 328 with appendix and index, and 22 plates. New York and London: McGraw-Hill Book Co., Inc., 1926.

The basic principles of safety organizations are dealt with at length in this new volume by the director of the Safety Engineering Division of the National Bureau of Casualty and Surety Underwriters. The writer's unusual experience in industrial safety has provided the volume with an outline of proved technic based on sound and logical principles.

The relations of safety to production, plant efficiency, and human relations are well presented. Plans for the organization and operation of the various types of safety committees are completely described. A complete index of accident report forms, of instructions to safety committees, of form letters and rating sheets is presented in an appendix to the book.

The book aims to furnish industrial executives with information about the safety movement and the essential principles needed for successful accident prevention. As a reference for safety engineers it would seem to be almost indispensable.—*Chas. F. Horan.*

BOOKS RECEIVED

Books received are acknowledged in this column, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers and as space permits.

INTERNATIONAL CLINICS. Volume III. Thirty-Sixth Series, 1926. Cloth. Pp. 310 with illustrations and index. Philadelphia and London: J. B. Lippincott, Co., 1926.

THE FINANCING OF SOCIAL WORK. By *Arthur W. Procter*, Formerly Budget Adviser to the City of Pittsburgh and Staff Member, President's Commission on Economy and Efficiency, and *Arthur A. Schuck*, Assistant National Field Director, Boy Scouts of America, and Adviser on Finance. With a Foreword by Mortimer L. Schiff, Internationally Known Philanthropist and Banker. Cloth. Pp. xii, 260 with appendixes and index. Chicago and New York: A. W. Shaw Co., 1926.

THE OPHTHALMIC YEAR BOOK. Volume XXII, containing Bibliographies, Digests and Indexes of the Literature of Ophthalmology for the year 1925. Edited by *William H. Crisp*, with collaboration of others. Cloth. Pp. 315 with illustrations and indexes. Chicago: Ophthalmic Publishing Co., Sept., 1926.

PRIMARY GYMNASTICS: THE BASIS OF RATIONAL PHYSICAL DEVELOPMENT. By *Niels Bukh*, Principal, Gymnastikhojskolen, Ollerup, Denmark. Translated from the second Danish edition by F. Braae Hansen, Lecturer, State Training College, Hadersley, Denmark; Late Master of Method, College of Hygiene and Physical Education, Dumfermline, Scotland: and F. de H. Bevington, Swedish

State Diploma (Dr. Arvedson's Institute, Stockholm) and Gymnastikhojskolen, Ollerup. Cloth. Pp. xii, 148 with illustrations. New York: E. P. Dutton & Co., 1926.

HYGIENE. A TEXTBOOK FOR COLLEGE STUDENTS, WITH INTRODUCTORY SECTIONS ON ANATOMY AND PHYSIOLOGY, AND PATHOLOGICAL CONDITIONS. By *Florence Lyndon Meredith*, M.D., College Physician, Professor of Hygiene, Smith College, Northampton, Mass. Cloth. Pp. xiii, 719 with illustrations, appendixes, bibliography, and index. Philadelphia: P. Blakiston's Son & Co., 1926.

INTERNATIONAL CLINICS. Volume IV. Thirty-Sixth Series, 1926. Cloth. Pp. 308 with illustrations and index. Philadelphia and London: J. B. Lippincott Co., 1926.

TRANSFUSION OF BLOOD. By *Henry M. Feinblatt*, M.D., Assistant Clinical Professor of Medicine, the Long Island College Hospital, Brooklyn, N. Y.; Hematologist to the United Israel-Zion Hospital; Pathologist to St. Peter's Hospital; Assistant Attending Physician to the King's County Hospital; Hematologist to the Shore Road Hospital; Author of "Clinical Laboratory Medicine." Cloth. Pp. 137 with index; 24 illustrations. New York: The Macmillan Co., 1926.